

**UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE
NATIONAL GEODETIC SURVEY**

**INTERNATIONAL EARTH ROTATION & REFERENCE SYSTEM SERVICES
ST. CROIX, USVI LOCAL SITE SURVEY REPORT**



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Introduction

During May 2017, the National Geodetic Survey conducted a high precision local site survey at the National Radio Astronomy Observatory's Very Long Baseline Array site located in St. Croix, US Virgin Islands. Data collection consisted of coordinate measurement procedures incorporating absolute laser tracker and Global Positioning System (GPS) observations using survey grade instrumentation. The primary objective of the survey was to establish high precision local ties, referenced to the International Terrestrial Reference Frame (ITRF2014), for technique instrument reference marks associated with a radio telescope, sometimes used for Very Long Baseline Interferometry (VLBI) and a Global Navigation Satellite System (GNSS) antenna. This report documents the instrumentation and methodologies used to collect the geo-spatial data set and data reduction and analysis procedures used to compute the local ties.

1. Site Description

Site Name: Sainte Croix (USVI)
Country Name: UNITED STATES OF AMERICA
Longitude: E 295° 25'
Latitude: N 17° 26'
Tectonic plate: CARB

SGT Instrument	Name	DOMES#	Description/a.k.a.
VLBI	CRO1	43201M001	Instrument Reference Mark
GPS	CROA		GPS Antenna Reference Point
GPS	CRO2		GPS Antenna Reference Point
VLBI	7615	43201S001	Conventional Reference Point

Table 1 – Space Geodetic Technique Instruments (SGT) located at the site.

2. Instrumentation

2.1. Tacheometers

2.1.1. Description

Leica AT402 (Absolute Laser Tracking system)

S/N: 392045

Specifications

Angular measurement uncertainty of instrument: $\pm 0.5''$

Combined uncertainty of distance measurement throughout range of instrument: ± 0.014 mm

2.1.2. Calibrations

Leica AT402, serial number 392045, certified by Leica Geosystem AG Heerbrugg, Switzerland on 08/28/2013

2.1.3. Auxiliary Equipment

Wild NL Collimator, S/N: 40145

Pointing accuracy, 1: 200,000

Leica ATC meteo-station, S/N D214.00.000.002

Accuracy:

Air temperature +/- 0.3^o C

Pressure +/- 1 hPa

Relative Humidity +/- 5%

2.2. GPS Units

2.2.1. Receivers

Trimble NetR5, P/N: 62800-00, S/Ns: 4619K01307, 4624K01647, and 4624K01631

Specifications for Static GPS Surveying:

Horizontal: +/- 5 mm + 0.5 ppm RMS

Vertical: +/- 5 mm + 1 ppm RMS

2.2.2. Antennas

Topcon GPS/GLONASS/Galileo choke ring antenna, model CR-G3, P/N: 1-044301-01
S/Ns 383-1614, -1613 and -1628

2.2.3. Analysis software, mode of operation

Post-processing and adjustment were undertaken using NGS's Online Positioning User Service (OPUS) Projects, an interactive web page. OPUS Projects uses as an underlying multi-baseline processor, NGS's Program for Adjustment of GPS Ephemerides (PAGES) software.

2.3. Leveling

2.3.1. Leveling Instruments

No leveling instruments used during the execution of this survey.

2.3.2. Leveling Staffs

No leveling equipment used during the execution of this survey.

2.3.3. Checks carried out before measurements

Not applicable

2.4. Tripods

Standard wooden surveying tripods, with collapsible legs, used to support surveying instrumentation centered over all permanent ground network marks.

2.5. Forced Centering Devices

A wild slip leg type wooden tripod, incorporating a Leica GDF321 tribrach and standard tribrach adapter were used to support target/reflectors at all ground control marks. Tripod tribrachs were plumbed over ground control mark reference points using a Wild NL Collimator, then “leveled up” using a Leica GZR3 carrier with longitudinal level vial. For all ground control marks, the reference point is considered to be the bottom center of a 0.001 m drill hole near the center of the survey disk.

Tripod heights, or the vertical distance from the ground control mark reference point to the top center of the tribrach adapter, were measured using; the laser tracking system, two 1.5 inch target/reflectors with 25 mm holders and a Kern trivet. A Kern trivet was plumbed over the ground control mark reference point using a forced centering pin attachment. The top of the forced centering pin was “leveled up” using the trivet’s integrated circular bubble. Measurements were then taken to a target/reflector and holder resting on the top center of the forced centering pin, see Figure 1.

Measurements were next taken to a second target/reflector and holder resting on the top center of the tribrach adapter, see Figure 2. The difference in height between these two sets of measurements, including a vertical offset value of 0.0940 m to account for use of the forced centering pin, represents the height of the tripod above the ground control reference mark, see Figure 3.



Figure 1 – A 1.5-inch reflector, resting in a reflector holder, resting on the top center of a Kern trivet forced-centering pin.



Figure 2 – A 1.5-inch reflector, resting in a reflector holder, resting on the top center of tribrach adapter.



Figure 3 – Target reflectors resting on top center of trivet forced centering pin and top center of tribrach adapter.

2.6. Targets, Reflectors and Accessories

Leica Break Resistant 1.5-inch reflector, part # 576-244

Centering of Optics: $\leq \pm 0.01\text{mm}$

Leica Tripod Adapter, part # 575-837

Leica Reflector Holder 1.5-inch, part # 577-126

Leica Reflector Holder 1.5-inch, part # 577-104

All absolute laser tracker measurements were taken to Leica 1.5-inch Break Resistant Reflectors, serving as both target and reflector. Reflectors were affixed to tribrachs using a combination of a Leica 1.5-inch reflector holder and Leica Tripod Adapter attached to a standard tribrach adapter.

3. Measurement Setup

3.1. Ground Network

Ground network marks are monumented for future reference. The terrestrial survey ties them together in a local coordinate system using high precision horizontal/zenith angles and distance measurements. Non-monumented, or temporary marks, (TP01, TP02 and TP03) were used this survey to facilitate alignment of the absolute tracker measurements.

3.1.1. Listing

Current Survey	DOMES	IERS 4-char code	Current Survey id	Previous Survey Point Name	NGS PID
Ground Network Marks					
ST CROIX VLBA NO 2	n/a	n/a	RM02	new this survey	n/a
ST CROIX VLBA NO 3	n/a	n/a	RM03	new this survey	n/a
ST CROIX VLBA NO 4	n/a	n/a	RM04	new this survey	n/a
SGT Instrument Reference Mark					
ST CROIX IRM	43201M001	CRO1	CRO1	VLBA RM 1 JPL 4023	n/a
SGT Conventional Reference Points					
CRO1 ARP	n/a	n/a	CROA	-new this survey-	n/a
CRO2 ARP	n/a	n/a	CRO2	-new this survey-	n/a
SGT 7615 CRP	43201S001	7615	7615	ST CROIX VLBA ANT	n/a

Table 2 – Listing of Ground Network Marks, SGT Instrument Reference Marks and SGT Conventional Reference Points.

Ground Network Marks

ST CROIX VLBA NO 2(RM02):

The mark is a 0.001 m hole drilled into the center of a “cross arrow”, cast in the top center of a NGS “reference mark” type brass survey disk. The mark is set in the top center of a concrete post type monument. The disk is stamped ST CROIX VLBA NO 2 2016.



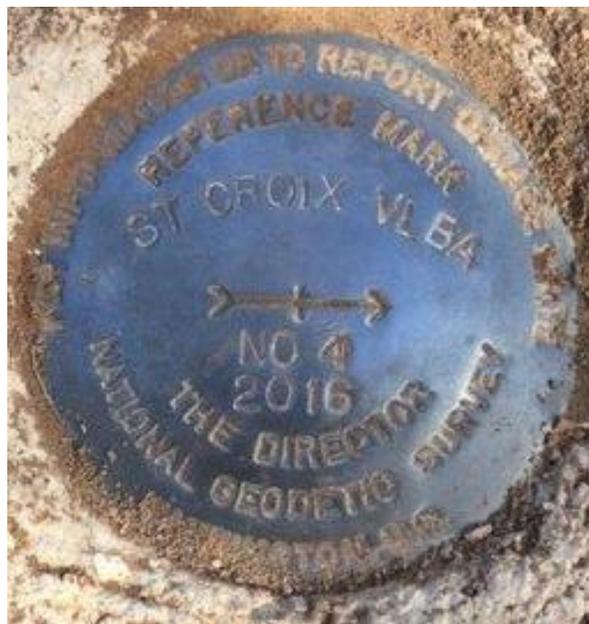
ST CROIX VLBA NO 3(RM03):

The mark is a 0.001 m hole drilled into the center of a “cross arrow”, cast in the top center of a NGS “reference mark” type brass survey disk. The mark is set in the top center of a concrete post type monument. The disk is stamped ST CROIX VLBA NO 3 2016.



ST CROIX VLBA NO 4(RM04):

The mark is a 0.001 m hole drilled into the center of a “cross arrow”, cast in the top center of a NGS “reference mark” type brass survey disk. The mark is set in the top center of a concrete post type monument. The disk is stamped ST CROIX VLBA NO 4 2016.



Instrument Reference Marks

ST CROIX IRM: The VLBA Instrument Reference Mark (IRM) is a dimple cast into the top center of a stainless steel plate set in the top center of a FLINN concrete pier set to a depth of 3.0 m. The IRM is occupied by IGS tracking station CRO1. The plate is inscribed ST CROIX VLBA RM-1 1994.



Figure 4 – ST CROIX IRM Instrument Reference Mark

3.1.2. Map of Network



Figure 5 – Ground control network map.

3.2. Representation of Technique Reference Points

The conventional reference point (CRP), a.k.a. invariant reference point, is a theoretical point. For the ST CROIX VLBA instrument, the CRP can be defined as the intersection of the azimuth axis with the common perpendicular of the azimuth and elevation axis (Johnston et al, 2004).

3.2.1. VLBI

SGT 7615 CRP - The National Radio Astronomy Observatory operates the Very Long Baseline Array (VLBA). SGT 7615 is one of 10 instruments comprising the VLBA. This instrument is used for a variety of astronomic science including periodic VLBI measurements. SGT 7615 is a 25-m AZEL type antenna. Coordinates for the CRP associated with SGT 7615 were determined indirectly this survey by means of a circle-fitting routine, using horizontal/vertical angle and distance measurements to a target affixed to the antenna during different rotational sequences.



Figure 6 – SGT 7615 25-m radio telescope

3.2.2. GPS

CRO1 ARP - The National Aeronautical & Space Administration's Jet Propulsion Laboratory operates this GPS tracking station. The station is included in the International GNSS Service (IGS) tracking network. The antenna type at time of this survey was a Javad, IGS antenna code JAVRINGANT_DM, part number 01-570300-01, (S/N: 00843). The Antenna Reference Point (ARP) is reported by the IGS to be centered horizontally over the IRM, with a vertical offset of 0.64352 m. Without removal of the antenna, the IRM is not accessible for direct occupation of survey instrumentation. Coordinates for the IRM associated with CRO1 were determined this survey by a circle fitting routine. A site log for CRO1 is available at the IGS ftp site:

http://www.igs.org/igsnetwork/network_by_site.php?site=cro1



Figure 7 – IGS network station CRO1 ARP

CRO2 ARP- The National Aeronautical & Space Administration’s Jet Propulsion Laboratory operates this GPS tracking station. The station is not included in the International GNSS Service (IGS) tracking network. The antenna type at time of this survey was a Javad, IGS antenna code JAVRINGANT_DM, part number 01-570300-01, (S/N: 00769). The antenna is not centered over a reference mark. For this instrument, the CRP is coincident with the ARP. Coordinates for the ARP associated with CRO2 ARP were determined this survey by a circle fitting routine. No site log is available for CRO2 ARP. For more information contact JPL.



Figure 8 – GNSS tracking station CRO2 ARP

4. Observations

4.1. Conventional Survey

The conventional survey was completed using a high precision absolute laser tracker system, the Leica AT402. Like a total station tachometer, the laser tracker measures horizontal angles, vertical angles, and distances to retro-reflector targets located at features of interest.

The resection principle was employed to measure coordinates of features of interest indirectly. Reference marks were occupied with reflector targets mounted on tripods. Temporary points were also established by affixing 0.5 m range poles to stable surfaces of convenience and mounting reflector targets. The laser tracker instrument did not occupy the reference marks directly but was instead setup at arbitrary locations between the stations. At each instrument occupation, a series of measurements were taken to all visible target reflectors. By observing the same target reflectors from different instrument occupations, the relative positions of both the instrument and the features of interest were established.

The resection procedure was chosen to take advantage of the AT402’s high precision capabilities and to mitigate setup errors. By setting up at arbitrary points rather than over marks, horizontal and vertical instrument centering errors were virtually eliminated. Likewise, the reference marks were occupied with tripods and target reflectors, then left undisturbed for the duration of the survey. While the vectors between stations were not observed directly, the AT402’s distance measurements are precise enough to determine relative positions with sub-millimeter accuracies. See figure 9 for a diagram of the included network stations.

As part of the observation routine, all angle and distance measurements to ground marks and temporary points were observed a minimum of three times. Double centering of the instrument was employed, measuring in both phase I and phase II. The AT402 utilizes a meteorological sensor to

monitor temperature and barometric pressure continuously. Meteorological observations are used to compute refractive index corrections at the time of measurement and applied automatically.

Data collection software Spatial Analyzer was used for recording AT402 observations and to perform field-level data quality checks. For a complete listing of unadjusted and adjusted observations, consisting of horizontal direction, zenith angles, slope distances, and target heights see Star*Net output file StCroix.lst.

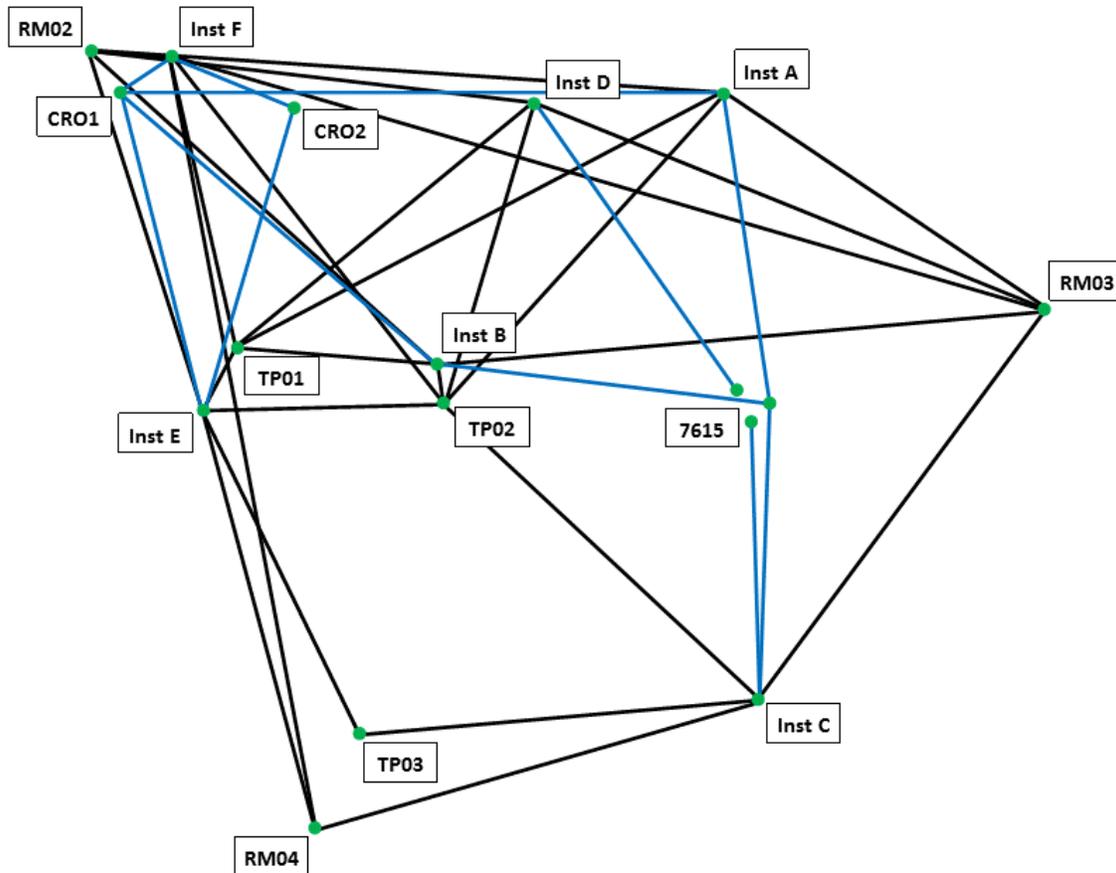


Figure 9 – Network diagram

4.2. Leveling

No leveling was required to complete this survey.

4.3. GPS

GPS data was collected for the purpose of determining high-precision, 3-dimensional IGS08(epoch date of survey 2017/05/14, aka eds) coordinates for ground network marks (ST CROIX IRM (a.k.a CRO1), ST CROIX RM NO 2, ST CROIX RM NO 3 and ST CROIX RM NO 4). For the purpose of this survey, IGS08 is aligned to ITRF2008 and are interchangeable. Final adjusted coordinates were further transformed to ITRF2014(eds) using NGS program HTDP. GPS data collection consisted of

simultaneous and long-session observations conducted over multiple days. GPS-derived coordinates for these three marks were used to align or transform the local terrestrial network to ITRF2014(eds).

4.4. General Comments

As noted earlier, determining the local coordinates of the SGT 7615 CRP was achieved using an indirect approach. The “circle fit” theory is described herein. A point, as it revolves about an axis, scribes a perfect arc. The arc defines a perfect circle and a plane simultaneously. The axis can then be seen as it passes through the center of the circle, orthogonal to the plane. By assigning coordinates to the points observed along an arc rotated about an axis, one can assign parameters to the axis relative to an established local coordinate system.

Tracker measurements project coordinates from the local ground network to a target reflector attached to a geodetic technique instrument as it moves about the instrument’s axis, thereby providing the necessary information to locate a single axis. The same procedure must be done for the opposing axis of the instrument in the same local reference frame. The point along the primary axis that is orthogonal to the secondary axis is the CRP associated with the SGT.

In practice, precise observations involving a single target reflector secured to the telescope, measurements from at least two instrument locations, and numerous measurements per axis serve to ensure a millimeter level of positional precision is achieved. SGT 7615 CRP was determined in this manner.

Local coordinates for; ST CROIX IRM, CRO1 ARP and CRO2 ARP were determined using a circle fitting routine. For ST CROIX IRM, 3-dimensional measurements were taken to a target reflector at multiple points along the circumference of an antenna offset pin resting in the reference point of the IRM (see figure 10). A sufficient number of points were measured around the circumference of the offset pin to scribe a circle in space. Corrections were applied to account for reflector and holder offset constants. Coordinates corresponding to the center of the scribed circle and theoretically the center of the IRM reference point were computed. Measurements were taken from at least two independent locations for redundancy.



Figure 10 – Target/reflector scribing a circle around the antenna offset pin.

For CRO1 ARP and CRO2 ARP, 3-dimensional measurements were taken to a target reflector at multiple points along the circumference of the antenna preamp, at a point where it meets the bottom of the antenna ground plane (see figure 11). A sufficient number of points were measured around the circumference of the preamp to scribe a circle in space. Corrections were applied to account for reflector and holder offset values and for mechanical dimensions of the preamp. Coordinates corresponding to the center of the scribed circle and theoretically the ARP were computed. Such measurements were taken from at least two independent locations for redundancy.



Figure 11 – Target/reflector scribing a circle around the antenna preamp.

5. Terrestrial Survey

5.1. Analysis software

Commercially available software Spatial Analyzer (version 2016.09.01_17917) was used to collect all field measurements with the absolute laser tracking system. The software was also used to conduct circle fitting computations for ST CROIX IRM IRM, CRO1 ARP and CRO2 ARP.

Commercially available, least squares adjustment software Star*Net (version 8,2,3,4253) was used to perform a classical 3-dimensional adjustment of the terrestrial data. Measurements included in the adjustment consisted of terrestrial observations of all ground network marks and intermediate target points affixed to the VLBA antenna. The adjustment yielded local 3-dimensional frame coordinates and variance-covariance information for all features surveyed. Terrestrial adjustment parameters and results can be found in Star*Net output file StCroix.lst. Terrestrial adjustment variance-covariance estimates can be found in the Star*Net output file StCroix.dmp.

AXIS 1.07 software, developed by Geoscience Australia (GA), was used to perform 3-dimensional arc fitting to compute a number of axes in space, which were in turn used to estimate the CRP associated with the SGT 7615. Circle fitting constraints can be found in AXIS input file setup.axs. Circle fitting parameters and results can be found in section 4.0 “Least Squares Estimation” of AXIS output file output.axs.

5.1.2. Topocentric Coordinates and Covariance

Topocentric coordinates and covariance information, from the classical adjustment of the terrestrial data, for ground network marks and VLBA targets can be found in section 2.1 “SOLUTION PARAMETER SUMMARY” and section 2.2 SOLUTION VARIANCE COVARIANCE MATRIX REDUCTION” in AXIS output file output.axs.

5.1.3. Correlation Matrix

Reduced correlation matrix information for the ground network marks, the CRP associated with SGT 7615 can be found in section 6, “SINEX GENERATION” in AXIS output file output.axs.

5.2. GPS Observations

NGS’s Online Positioning User’s Service (OPUS) Projects was used to post-process, analyze, and adjust GPS data and to compute 3-dimensional estimates of alignment station positions. Resulting adjusted positions can be found in OPUS-Projects output file “OP network.txt”. The tripod setup for ground network mark ST CROIX VLBA RM 2 shifted during data collection. Considering the uncertainty of when the shift in the setup might have occurred this station was not used for the local to geocentric frame transformation.

5.3. Additional Parameters

5.3.1. VLBA antenna Axis Offset Computation

AXIS software was used to compute the offset distance between the elevation and azimuthal axis. The offset value was computed to be 2.1383 ± 0.0003 m. The International VLBI Service reports the axial offset to be 2.1377 ± 0.0007 m. Offset computation results can be found in section 4.7 “IVP/TOUCH/INTERSECT PARAMETER VALUES AND THEIR PRECISION” of the AXIS output file output.axs.

5.3.2. GPS Antenna Reference Point Offset from Instrument Mark Computation

NGS Program INVERS3D was used to compute offset values from ST CROIX IRM to CRO1 ARP. Final coordinates for these marks, provided in Table 5, were used as input. Offset values were computed to be delta north 0.0003 m, delta east -0.0009 m and delta up 0.6435 m. The IGS reported offset was held as a constraint during the least squares adjustment of the terrestrial network data. Without removal of the antenna, the length of the offset pin resting inside of the IRM dimple could not be measured directly during the survey. The IGS reports the offset values to be delta north 0.000 m, delta east 0.000 m and delta up 0.6435 m (offset pin constant).

5.4. Transformation

Local tie vectors from the terrestrial survey were accurately aligned, or transformed, from a geodetic frame to ITRF2014(eds) using AXIS software. For the alignment, AXIS requires coordinates in the desired reference frame and epoch date at a minimum of three co-observed sites (ST CROIX IRM, ST CROIX RM 3 and ST CROIX RM 4). The spatial integrity of the terrestrial survey is maintained throughout the transformation process. Transformation parameters and results can be found in section 3. “APRIORI FRAME ALIGNMENT” in the AXIS output file output.axs.

5.5. Description of SINEX generation

AXIS was used to generate a final solution output file in SINEX format with full variance-covariance matrix information. The following SINEX file naming convention, adopted by GSA for local survey data, was also used for this survey.

XXXNNNNYYMMFV.SNX

Where:

XXX is a three-character organization designation

NNNN is a four-character site designation

YY is the year of the survey

MM is the month of the survey

F is the frame code (G for global, L for local)

V is the file version

Axis generated SINEX file *NGSCRO11705GA.snx* is found in the [Attachment: SINEX File](#).

5.6. Discussion of Results

Least-Squares Estimates of Terrestrial Observations

A classical 3-dimensional adjustment of terrestrial observation was conducted using Star*Net. The adjustment produced geodetic coordinates, in a geodetic reference frame, for all stations included in the survey and the targets intended for use in determination of SGT 7615 CRP. A statistical summary from the adjustment is included in Table 3.

For additional details concerning the classical adjustment of the terrestrial survey, see Star*Net output file StCroix.lst.

Adjustment Statistical Summary			
=====			
Iterations	=		5
Number of Stations	=		84
Number of Observations	=		469
Number of Unknowns	=		267
Number of Redundant Obs	=		202
Observation	Count	Sum Squares of StdRes	Error Factor
Directions	155	63.381	0.974
Distances	156	34.632	0.718
Az/Bearings	1	0.000	0.000
Zeniths	156	78.505	1.081
Elev Diffs	1	0.001	0.053
Total	469	176.519	0.935
The Chi-Square Test at 5.00% Level Passed			
Lower/Upper Bounds (0.903/1.097)			

Table 3 – Terrestrial survey classical 3-dimensional adjustment statistical summary

AXIS was used to produce coordinates and variance-covariance estimates for the CRP associated with SGT 7615. A StarNet output file (StCroix.dmp), containing coordinates and associated variance-covariance estimates for main scheme network marks and targets affixed to the VLBA antenna, was used as input. AXIS performed 3-dimensional arc fitting to compute multiple axes in space, which were in turn used to estimate the CRP associated with SGT 7615. Table 4 contains statistics from the least squares solution..

LEAST SQUARES SOLUTION		
# OF TARGETS	:	5
# OF IVP ESTIMATES	:	6
# OF COORDINATE-OBSERVATIONS	:	204
# OF UNKNOWN	:	83
# OF CONDITIONS	:	126
# OF CONSTRAINTS	:	53
# OF ADD. CONSTRAINTS	:	8
# OF CONSTRAINTS TOTAL	:	61
DEGREES OF FREEDOM	:	308
ITERATIONS TO COMPLETE	:	2
MAXIMUM RESIDUAL (METRE)	:	0.00105
VARIANCE (CONDITIONS)	:	0.50203
VARIANCE (CONSTRAINTS)	:	0.00061
VARIANCE (APRIORI)	:	0.00000
VARIANCE FACTOR	:	0.50264
SIGMA	:	0.70897

Table 4 –Statistical summary from least squares adjustment of VLBA targets

Final Coordinate Listing

AXIS was used to compute final coordinate estimates, aligned to reference frame ITRF2014 (eds), for all ground network marks, the IRM and ARPs associated with CRO1, CRO2 and SGT 7615 CRP determined during the current NGS survey. See Table 5 for the compiled coordinate listing. Final coordinates for the CRP associated with SGT 7615 and the IRM for CRO1 are in SINEX format in the Attachment and in AXIS output file NGSCRO11705GA.snx.

<i>SITE</i>	<i>X (m)</i>	<i>Y (m)</i>	<i>Z (m)</i>	<i>SX (m)</i>	<i>SY (m)</i>	<i>SZ (m)</i>
<i>CRO1</i>	<i>2607771.3031</i>	<i>-5488076.5816</i>	<i>1932767.9412</i>	<i>0.0001</i>	<i>0.0001</i>	<i>0.0001</i>
<i>RM02</i>	<i>2607767.3239</i>	<i>-5488076.2118</i>	<i>1932771.9178</i>	<i>0.0001</i>	<i>0.0001</i>	<i>0.0001</i>
<i>RM03</i>	<i>2607870.6967</i>	<i>-5488043.5035</i>	<i>1932746.1890</i>	<i>0.0001</i>	<i>0.0001</i>	<i>0.0001</i>
<i>RM04</i>	<i>2607803.2842</i>	<i>-5488092.2889</i>	<i>1932690.0078</i>	<i>0.0002</i>	<i>0.0001</i>	<i>0.0001</i>
<i>7615</i>	<i>2607848.6748</i>	<i>-5488069.5012</i>	<i>1932739.7980</i>	<i>0.0002</i>	<i>0.0003</i>	<i>0.0002</i>
<i>CROA</i>	<i>2607771.5653</i>	<i>-5488077.1355</i>	<i>1932768.1378</i>	<i>0.0002</i>	<i>0.0001</i>	<i>0.0002</i>
<i>CRO2</i>	<i>2607789.5837</i>	<i>-5488069.3052</i>	<i>1932766.4639</i>	<i>0.0002</i>	<i>0.0002</i>	<i>0.0002</i>

Table 5 –Listing of final ITRF2014(eds) coordinate estimates for ground network marks, SGT 7615 IRM and ST CROIX IRM

Table 6 provides the local tie vectors, determined during this survey, emanating from ST CROIX IRM (CRO1) to SGT 7615 CRP, CRO1 ARP and CRO2 ARP. NGS program INVERSE3D was used to compute the tie vector information.

```

First Station : ST CROIX IRM (NGS epds)
-----
X = 2607771.3031 m LAT = 17 45 24.83894 North
Y = -5488076.5816 m LON = 64 35 3.54688 West
Z = 1932767.9412 m EHT = -31.9690 Meters

Second Station : SGT 7615 CRP (NGS epds)
-----
X = 2607848.6748 m LAT = 17 45 23.70116 North
Y = -5488069.5012 m LON = 64 35 1.07142 West
Z = 1932739.7980 m EHT = -15.0175 Meters

DX = 77.3717 m DN = -34.9794 m
DY = 7.0804 m DE = 72.9223 m
DZ = -28.1433 m DU = 16.9510 m

Second Station : CRO1 ARP (NGS epds)
-----
X = 2607771.5653 m LAT = 17 45 24.83895 North
Y = -5488077.1355 m LON = 64 35 3.54691 West
Z = 1932768.1378 m EHT = -31.3255 Meters

DX = 0.2621 m DN = 0.0003 m
DY = -0.5539 m DE = -0.0009 m
DZ = 0.1966 m DU = 0.6435 m

Second Station : CRO2 ARP (NGS epds)
-----
X = 2607789.5837 m LAT = 17 45 24.78054 North
Y = -5488069.3052 m LON = 64 35 2.88036 West
Z = 1932766.4639 m EHT = -31.2067 Meters

DX = 18.2805 m DN = -1.7954 m
DY = 7.2764 m DE = 19.6342 m
DZ = -1.4773 m DU = 0.7623 m

```

Table 6 – Local tie vector emanating from ST CROIX IRM (meters)

6. Planning Aspects

Contact information

The primary contact for information regarding SGT 7615 is NRAO employee Eric Carlow. Eric's contact information is:

Eric Carlowe
National Radio Astronomy Observatory (NRAO)
Array Operations Center
P.O. Box O
1003 Lopezville Road
Socorro, NM 87801-0387
Phone: (575) 835-7000, Fax: (575) 835-7027
ecarlowe@nrao.edu

Recommendations:

Plan all measurements to VLBA antenna targets around weekly maintenance days to minimize impact on the NRAO data collection mission. At the time of this survey, every Wednesday is a maintenance day. Once each month the VLBA has two consecutive maintenance days during a single week. This would be the optimal week to conduct the local site survey.

Shipments to/from ST. Croix are considered to be "international" and have to pass through customs. Also, UPS does not deliver packages to the observatory. Plan to ship to/from the project at the UPS shipping center located at the airport.

7. References

7.1. Name of person(s) responsible for observations

Kendall Fancher (Kendall.Fancher@noaa.gov)
Benjamin Erickson (Benjamin.Erickson@noaa.gov)

National Geodetic Survey
15351 Office Drive
Woodford, VA 22580
Phone – (540) 376-6535

7.2. Name of person(s) responsible for analysis

Kendall Fancher (Kendall.Fancher@noaa.gov)
Benjamin Erickson (Benjamin.Erickson@noaa.gov)

National Geodetic Survey
15351 Office Drive
Woodford, VA 22580
Phone – (540) 376-6531

7.3. Location of observation data and results archive

National Geodetic Survey
Instrumentation & Methodologies Branch
15351 Office Drive
Woodford, VA 22580
Phone – (540) 373-1243

Attachment: SINEX Format

```

%=SNX 1.00 AUS 17:202:51969 AUS 17:134:00000 17:135:00000 C 00012 2 X
+FILE/REFERENCE
DESCRIPTION      Terrestrial Survey Tie
OUTPUT           SSC SINEX
CONTACT
SOFTWARE         _____
                 axis version 1.07
HARDWARE
INPUT            _____
                 Terrestrial Survey Solution
-FILE/REFERENCE
+FILE/COMMENT
* axis software by John Dawson Geoscience Australia
-FILE/COMMENT
+SITE/ID
RMO1  A 43201M001 C ST CROIX IRM
      -64 35 3.5 17 45 24.8 -32.0
7615  A 43201S001 C SGT 7615 CRP
      -64 35 1.1 17 45 23.7 -15.0
CRO1  A 43201M001 C ST CROIX CRO1 ARP      -64 35 3.5 17 45 24.8 -31.3
CRO2  A ----- C ST CROIX CRO2 ARP
      -64 35 2.9 17 45 24.8 -31.2
-SITE/ID
+SITE/DATA
RMO1  A 1 RMO1  A 1 17:134:00000 17:135:00000 --- 17:134:43200
7615  A 1 7615  A 1 17:134:00000 17:135:00000 --- 17:134:43200
CRO1  A 1 CRO1  A 1 17:134:00000 17:135:00000 --- 17:134:43200
CRO2  A 1 CRO2  A 1 17:134:00000 17:135:00000 --- 17:134:43200
-SITE/DATA
+SOLUTION/EPOCHS
RMO1  A 1 C 17:134:00000 17:135:00000 17:134:43200
7615  A 1 C 17:134:00000 17:135:00000 17:134:43200
CRO1  A 1 C 17:134:00000 17:135:00000 17:134:43200
CRO2  A 1 C 17:134:00000 17:135:00000 17:134:43200
-SOLUTION/EPOCHS
+SOLUTION/STATISTICS
VARIANCE FACTOR          5.026395903303587e-01
SQUARE SUM OF RESIDUALS  1.548129938217505e+02
NUMBER OF OBSERVATIONS   320
NUMBER OF UNKNOWNNS     12
-SOLUTION/STATISTICS
+SOLUTION/ESTIMATE
1 STAX  RMO1  A 1 17:134:43200 m 2 2.60777130313314e+06 1.00000e-04
2 STAY  RMO1  A 1 17:134:43200 m 2 -5.48807658159368e+06 1.00000e-04
3 STAZ  RMO1  A 1 17:134:43200 m 2 1.93276794124172e+06 1.00000e-04
4 STAX  7615  A 1 17:134:43200 m 2 2.60784867481126e+06 2.91566e-04
5 STAY  7615  A 1 17:134:43200 m 2 -5.48806950117728e+06 4.67391e-04
6 STAZ  7615  A 1 17:134:43200 m 2 1.93273979798011e+06 2.47188e-04
7 STAX  CRO1  A 1 17:134:43200 m 2 2.60777156526597e+06 2.27222e-04
8 STAY  CRO1  A 1 17:134:43200 m 2 -5.48807713545886e+06 1.65863e-04
9 STAZ  CRO1  A 1 17:134:43200 m 2 1.93276813779702e+06 2.38745e-04
10 STAX CRO2  A 1 17:134:43200 m 2 2.60778958366561e+06 2.79539e-04
11 STAY CRO2  A 1 17:134:43200 m 2 -5.48806930524212e+06 2.13649e-04
12 STAZ CRO2  A 1 17:134:43200 m 2 1.93276646390657e+06 2.73162e-04

```

-SOLUTION/ESTIMATE

+SOLUTION/MATRIX_ESTIMATE U COVA

1	1	9.9999999997243e-09	5.46701337320573e-21	3.78858927021005e-20
1	4	9.9999999953876e-09	1.20013519930811e-13	-2.36734923609432e-14
1	7	9.9999999992585e-09	-1.59831829063562e-18	1.73491592229282e-19
1	10	9.9999999987937e-09	3.23135855496036e-14	-1.21505035869825e-15
2	2	1.0000000000244e-08	2.27415927723378e-20	-1.20016560416318e-13
2	5	1.00000000006116e-08	4.98173797952845e-14	1.59853816295686e-18
2	8	1.00000000002729e-08	2.20627487869012e-19	-3.23135856414275e-14
2	11	9.9999999991474e-09	2.55703439358263e-15	
3	3	1.00000000000067e-08	2.36764113296071e-14	-4.98228286480928e-14
3	6	1.00000000023512e-08	-7.75700792870656e-20	3.81675475795058e-19
3	9	9.9999999964773e-09	1.21526394863929e-15	-2.55711319299650e-15
3	12	1.00000000000663e-08		
4	4	8.50110039402907e-08	-8.23576328534903e-08	2.96770379176147e-08
4	7	2.93281248412933e-08	5.51097162511202e-09	-5.89455996151661e-09
4	10	2.83910847057085e-08	3.97905791188633e-09	-2.38370759787949e-09
5	5	2.18454411383329e-07	-6.15080759626975e-08	6.02082652183529e-09
5	8	1.46859064615863e-08	-1.74786121478240e-09	4.31215188317869e-09
5	11	1.77035347016507e-08	-5.97698228702710e-10	
6	6	6.11020934329167e-08	-2.92507636386600e-09	1.93878368454693e-10
6	9	1.72583632041312e-08	-1.19491411823598e-09	3.36558065942568e-11
6	12	1.84576490528273e-08		
7	7	5.16299361293009e-08	1.40068102644913e-08	-5.42745302411227e-09
7	10	2.95009709821301e-08	6.56353731961375e-09	-1.49532172508460e-09
8	8	2.75106362709079e-08	1.14067935278049e-08	7.33873113901618e-09
8	11	1.68402118171727e-08	4.32528091890535e-09	
9	9	5.69989444552299e-08	-9.00743610467193e-10	4.14446955135096e-09
9	12	2.73063501916483e-08		
10	10	7.81419111705583e-08	1.83184643080911e-08	-6.16235227602576e-09
11	11	4.56458632079904e-08	1.13639041398751e-08	
12	12	7.46172095381713e-08		

-SOLUTION/MATRIX_ESTIMATE U COVA

%ENDSNX